भारतीय मानक
Indian Standard

IS 16979 : 2018

बोरस्कोप और वीडियोस्कोप का उपयोग करते हुए दृष्टिक निरीक्षण के मार्गदर्शी सिद्धांत

Guidelines for Visual Inspection Using Borescopes and Videoscopes

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by the Non-Destructive Testing Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Visual Inspection, one of the oldest non-destructive testing methods, has gained a lot of importance in recent past because of its ability to detect surface flaws, which are more severe than subsurface flaws of similar type. Earlier, magnifying lenses and microscopes were the simple tools used for visual inspection. Later borescope gave an added advantage to inspect hard-to-reach areas such as inside surface of tubes and pipes having straight passage. With the advent of fiber optics another variant of rigid borescope known as 'Flexible Fibrescope' came into existence, for the inspection of curvilinear passage.

Development in the electronics of imaging technology has made it possible to display the image on a monitor of an object situated at a far distance. This has reduced the eye strain and fatigue normally encountered while using borescope. In a fibrescope, image of an object near distal end is transmitted through relay lenses housed in an image guide bundle. Optical image transfer suffers from loss in transmission resulting in poor quality of the image at eye piece. However, in a videoscope, image quality is far superior due to electronic transmission of an image signal from a charge-coupled device (CCD) imaging sensor at the distal tip to a monitor. State of the art videoscope consists of facilities such as 360° articulation of the distal tip, stereoscopic depth measurement, dimensional measurement, image recording and processing, image transfer, under water inspection etc.

Videoscopic examination of long tubes has become an essential requirement along with other non-destructive testing methods used for health monitoring of heat exchanger and steam generator tubes during in-service inspection campaign.

This document provides complete guidelines for visual inspection using borescopes and videoscopes. For better understanding, it highlights the construction details, type of borescope and working principle of videoscope. It also defines certain terminologies related to visual inspection, which will be helpful for equipment selection. Though, simple in use, yet videoscopes are associated with hazards and considering this a paragraph giving details of safety measures to be exercised while using borescopes, has been also included in this document, under the title 'General Precautions'.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

GUIDELINES FOR VISUAL INSPECTION USING BORESCOPES AND VIDEOSCOPES

1 SCOPE

1.1 This standard is intended to provide general guidance for the use of borescope and videoscope for visual examination or visual inspection of surfaces inside narrow tubes/pipes or difficult-to-reach chambers in order to detect the presence of imperfections or to assess condition and texture.

1.2 This standard specifies theory, working principle, functions and definitions of borescopes and related terms which will be helpful for conducting visual examinations using appropriate borescope.

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated were valid. All standards are subject to revision, and parties to agreements, based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below:

IS No.	*Title*
IS 13805 : 2004	General standard for qualification and certification of non- destructive testing personnel — Specification (*first revision*)

3 WRITTEN PROCEDURE REQUIREMENTS

Visual inspection using borescope and videoscope shall be performed in accordance with a written procedure, which shall, as a minimum, contain the requirements listed in the referencing code. If required referencing code or involving measurements of dimensions of discontinuities, procedure shall be qualified.

4 PERSONNEL QUALIFICATION

The personnel performing borescopic inspection shall have adequate and sound knowledge of the technique. If required by the referencing code, visual inspection shall be carried out by certified personnel with level of competence confirming to IS 13805.

5 INTRODUCTION

5.1 Visual inspection is non-destructive testing method that provides means of detecting and examining a variety of surface flaws, such as corrosion, contamination, surface finish and surface discontinuities on joints (for example, welds seals, solder connection and adhesive bonds).

5.2 Visual inspection is also the most widely used method for detecting and examining surface cracks, which are particularly important because of their relationship to structural failure mechanisms. Even when other nondestructive techniques are used to detect surface cracks, visual inspection often provides a useful supplement.

5.3 Visual testing is the oldest and most economical form of non-destructive testing. The use of optical instruments in visual testing is beneficial for two purposes:

a) to magnify discontinuities that cannot be detected by the unaided eye, and
b) to permit visual checks of areas not accessible to the unaided eye.

6 EQUIPMENT USED FOR VISUAL INSPECTION

6.1 Magnifier as an aid to vision is used for evaluating surface finish, surface shapes (profile and contour gauging) and surface microstructures. It is also used for comparing two surfaces. Reader lens is the simplest form of magnifier having 15 X magnifications.

6.2 Flexible or rigid borescopes for illuminating and observing internal, closed or otherwise inaccessible areas.

6.3 Image sensors for remote sensing or for the development of permanent visual records in the form of photographs, videotapes or computer-enhanced images.

7 MAGNIFYING LENSES

7.1 The object is placed close to the lens in order to obtain as great a magnification as desired. The distance from lens to object is adjusted until the object is in the lens depth of field and is in focus. The simplest form of a microscope is a single converging lens, often referred to as a simple magnifier.

7.2 Magnifiers can be grouped into four broad categories:

a) Conventional magnifier and reader;

b) Low power microscopes;
c) Medium power microscopes; and
d) High power microscopes.

8 BORESCOPE

8.1 A borescope is a long tubular optical device used for the visual inspection of surfaces inside narrow tubes/pipes or difficult-to-reach chambers. In its most basic form, borescope consists of four main units:

a) Light Source,
b) Objective lens at distal tip,
c) Eyepiece lens at viewing end, and
d) Relay lens in middle section.

Insertion tube, which may be rigid or flexible, connects objective lens at one end to the eyepiece lens on the opposite end through relay lenses. Inspection area of an object is illuminated by the light source and its image captured by the objective lens is transmitted through relay lenses to an eyepiece for viewing the area at a distance (*see* Fig. 1).

8.2 The objective is an arrangement of prisms and lenses mounted closely together. Its design determines the angle of vision, the field of view and the amount of light gathered by the system.

Function of the middle lenses is to conserve the light entering the system and conduct it through the borescope tube to the eyepiece with a minimum loss in transmission. The middle lenses are achromatic, each lens being composed of two elements with specific curvatures and indexes of refraction. This design preserves sharpness of the image and true color values.

8.3 The image formed at eyepiece is not real but an aerial image formed in the air between the lenses. Hence it is possible to provide diopter correction for the observer and distance correction for the object (focusing). Focus control at the viewing end provides adjustment for sharpness of the image and compensation for the eyesight variation of the inspectors. It also greatly expands the depth of field as compared to non-focusing or fixed focus design borescope.

A contact ring, through orbital scan control at the viewing end, permits rotation of the borescope through 360 degrees for scanning the object space without entangling the electrical cord.

8.4 Types of Borescope

Mainly borescope can be classified as rigid and flexible borescope, depending upon the design of the insertion tube.

8.4.1 *Rigid Borescope*

Objective, relay and eyepiece lenses are mounted in a rigid tube. Can be used only for limited applications with straight passage between observer and the area to be inspected (*see* Fig 2). (This type retains its original name that is, borescope.)

8.4.2 *Flexible Borescope*

Objective, relay and eyepiece lenses are mounted in a flexible tube. Mainly used in applications those do not have a straight passageway between observer and the area to be inspected. Flexible borescope can be further subdivided into two types namely:

a) Flexible Fiberscope — Light transmission through a bundle of optical fibers inside a flexible tube. A typical fiberscope consists of a light guide bundle,

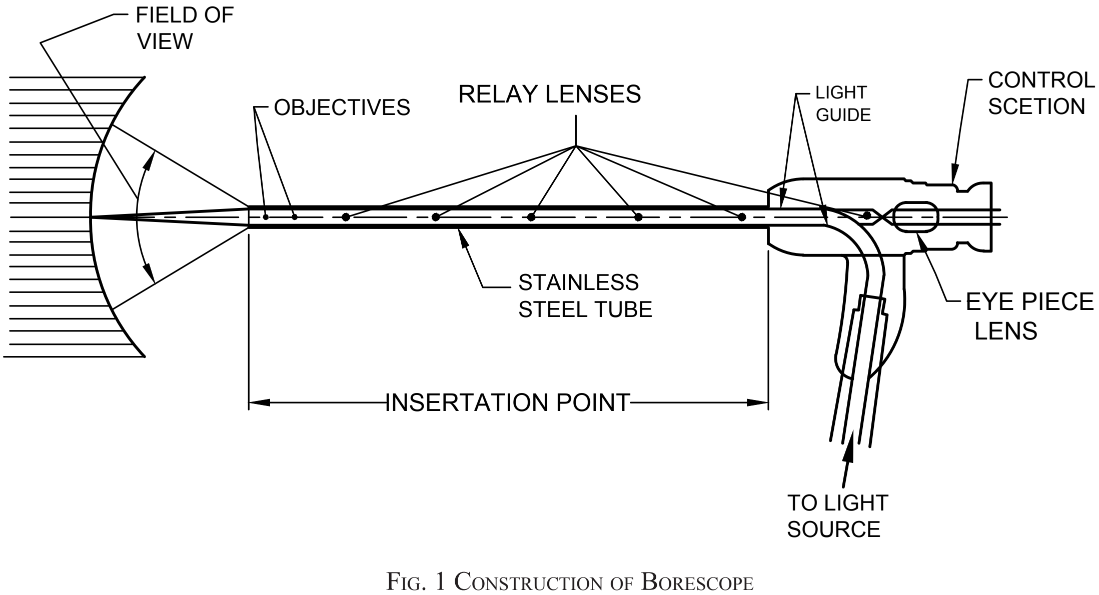


FIG. 1 CONSTRUCTION OF BORESCOPE

an image guide bundle, an interchangeable objective lens, viewing heads and remote controls for articulation of the distal tip (*see* Fig. 3).

b) Videoscope — Electronic transmission of image signal from a charge-coupled device (CCD) imaging sensor at the distal tip to a monitor, through wiring inside a tube (normally flexible). A typical videoscope consists of a light guide bundle, signal bus, an interchangeable objective lens, video monitor and remote controls for articulation of the distal tip.

Borescopes under 38 mm diameter are often made in pieces with the objective section 1 or 2 m in length. The additional sections are 1, 2 or 3 m long with threaded connections. These sections may be added to form borescopes with lengths up to 15 m for diameters under 37 mm (*see* Fig. 4). Flexible models are available in diameters from 1.4 to 13 mm and in lengths up to 12 m as single piece.

Borescope can also be classified as direct, right angle, forward oblique and retrospective vision

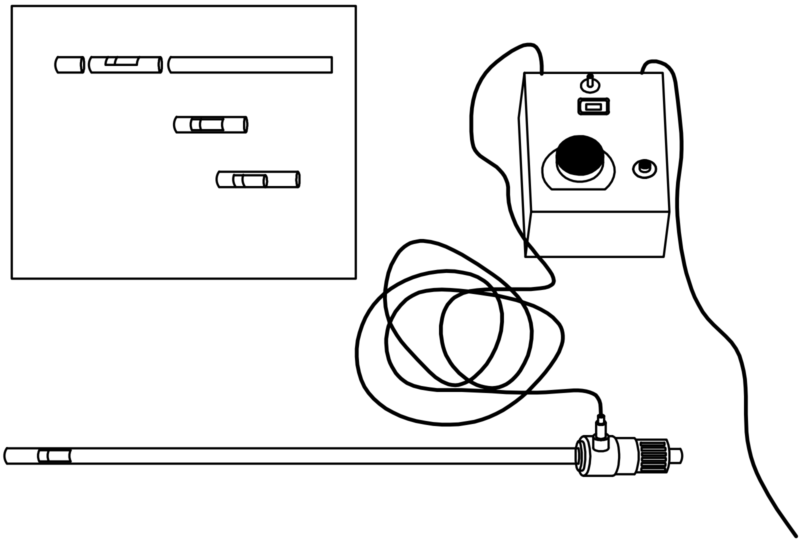


FIG. 2 A COMPLETE SET OF BORESCOPE
(INSET — INSERTION TUBE AND VIEWING HEADS)

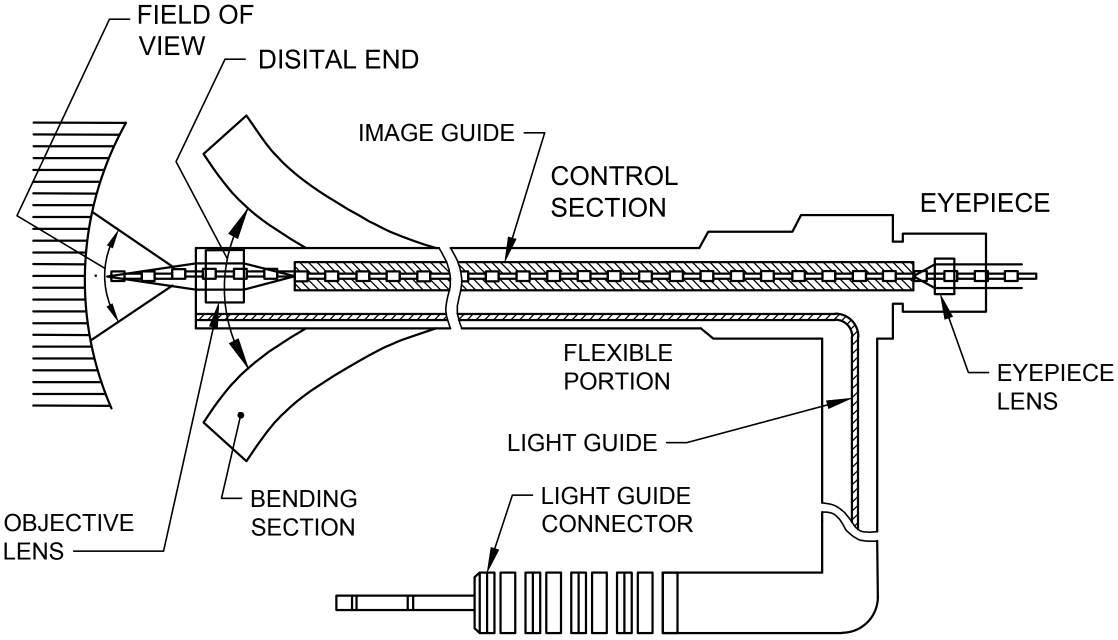


FIG. 3 CONSTRUCTION OF FIBRESCOPE

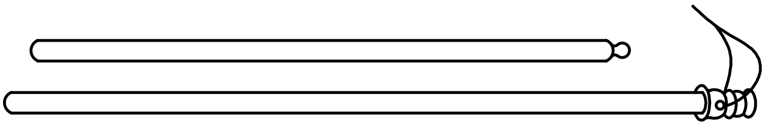


FIG. 4 LARGER DIAMETER BORESCOPE WITH EXTENSION PIECE

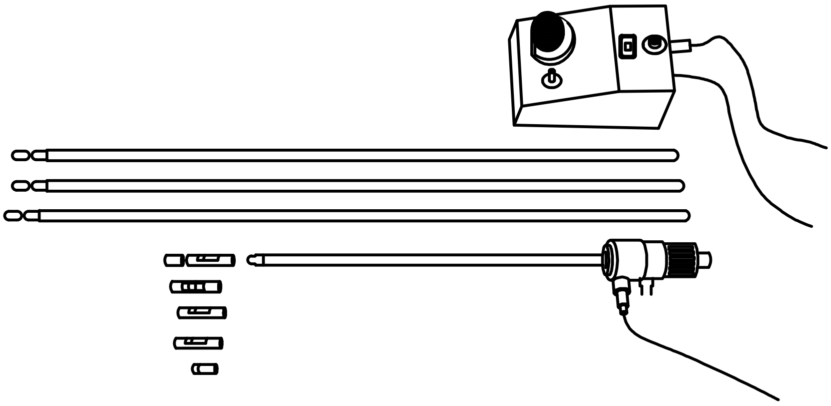


FIG. 5 BORESCOPE WITH EXTENSION PIECES AND DIFFERENT VIEWING HEADS

borescopes based on the design of the objective lens (*see* Fig. 5).

1) Direct Vision Borescope — The direct vision instrument provides a view directly forward with a typical visual area of about 19 mm at 25 mm distance from the objective lens. The light carrier is removable so that the two parts can be passed successively through a small opening.
2) Right Angle Borescopes — The right angle borescope is usually furnished with the light source positioned ahead of the objective lens. The optical system provides vision at right angles to the axis of the borescope and covers a working field of about 25 mm diameter at 25 mm from the objective lens.
3) Forward Oblique Borescopes — The forward oblique system is a design that permits the mounting of a light source at the end of the borescope yet also allows forward and oblique vision extending to an angle of about 55 degree from the axis of the borescope. A unique feature of this optical system is that, by rotating the borescope, the working area of the visual field is greatly enlarged.
4) Retrospective Borescope — The retrospective borescope has an integral light source mounted slightly to the rear of objective lens. For a bore with an internal shoulder whose surface must be accurately profiled, the retrospective borescope provides a unique method of accurate visual inspection.

Desirable properties of borescopic systems are large field of vision, no image distortion, accurate transmission of colour values and, adequate illumination.

The brightest images are obtained with borescopes of large diameter and short length. As the length of the borescope is increased, the image becomes less brilliant because of light losses from additional lenses required to transmit the image. Lenses are typically coated with anti-reflecting layers which provide maximum light transmission by minimizing the losses.

9 VIDEOSCOPES

Videoscopes with charge coupled device (CCD) probes involve the electronic transmission of color or black and white images to a video monitor.

9.1 Video Borescope Components

A video borescope has four main components:

a) a probe, with a charge coupled device embedded in the distal tip, which is located at the end of a insertion tube;
b) a video processor, to communicate signals to the monitor;
c) a monitor, black and white or color; and
d) an alphanumeric keyboard for entering identification references onto the display or into a permanent record.

9.2 Working Principle of Video Borescope

9.2.1 Video borescopes transmit images in the following way:

a) First, light is sent to the test area by fiber optic light guides or by light emitting diodes;

b) Fiber optic lighting can be used for either color or black and white imaging; and

c) Light emitting diodes are used only for black and white imaging, because they cannot transmit multicolored light.

9.2.2 The distal end of electronic videoscopes contains CCD chips, which consists of thousands of light-sensitive elements arrayed in a pattern of rows and columns. Once the light has reached the test area, the objective lens in the tip of the probe gathers reflected light from the test area, directs and focuses the image of an object on the surface of the CCD. Here light is converted to electrons that are stored in each picture element, or pixel of the CCD device. The image of the object is thus stored in the form of electrons on the CCD device. At this point a voltage proportional to the number of electrons at each pixel is determined electronically for each pixel site. This voltage is then amplified, filtered and sent to the input of video monitor (*see* Fig.6).

9.2.3 Video borescopes feature includes; remote four way steering control, right angle adapter for 90 degree viewing and the ability to measure accurately what is seen in the borescope image.

9.2.4 Video borescopes are easily coupled with such accessories as standard video recorders, telephone modems, electronic hardcopy devices or computer enhancement equipment.

9.2.5 With electronic videoscope, it is possible to:

a) Obtain electronic zooming of the image;

b) Adjust the brightness, colour, noise, contrast and sharpness of the image;

c) Record and retrieve still and moving image;

d) Record audio with the movie and still image; and

e) Transfer the image to a computer for viewing it on a monitor.

9.2.6 Videoscope with stereo optical adapter can perform following measurements:

a) Distance between two points;

b) Perpendicular distance between a point and a line;

c) Distance between two parallel lenses;

d) Depth and height of a point with respect to a reference plane;

e) Area of a profile; and

f) Distance between the distal end of the optical adapter and the subject.

9.3 Advantages of Videoscope Over Rigid Borescope

9.3.1 Rigid borescopes can cause eye strain and often require the operator to adopt awkward position to see through the eyepiece. Video borescopes eliminate these

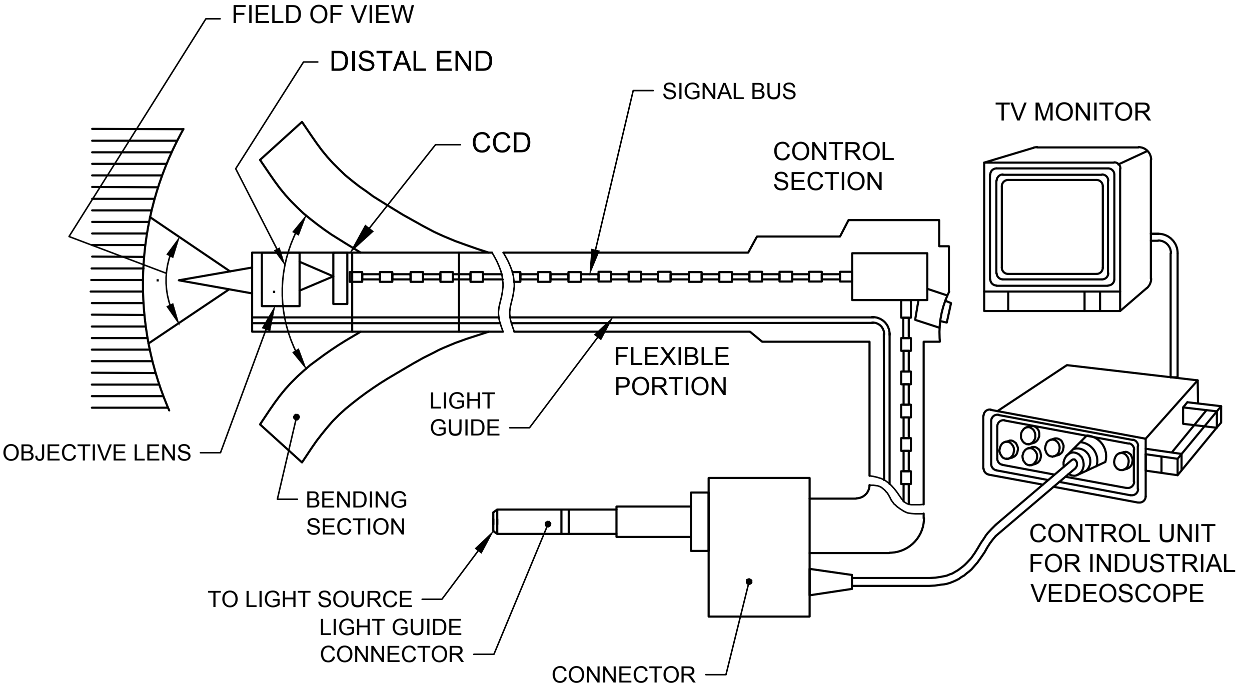


Fig. 6 Construction of Videoscope

problems by allowing the inspector to sit comfortably in front of a monitor.

By eliminating the time consuming task of refocusing, video borescopes with automatic focusing, make remote visual testing more efficient and less tiresome.

9.3.2 Video borescopes also allow multiple views of the same image, making evaluations more reliable and facilitating training. In fact, a given image can be transmitted simultaneously to any number of monitors at the site or by modem or satellite, to remote locations.

10 GENERAL GUIDELINES FOR USING BORESCOPE

10.1 Depending upon the diameter of the tube selection of borescope shall be done. A minimum clearance of 5 mm is recommended between the object and borescope for easy insertion and removal.

10.2 Based on the distance of the location to be inspected from the open end, borescope of appropriate length shall be selected. In case borescope of sufficient length is not available, extension piece shall be attached to obtain the required length of the borescope. Care must be exercised to screw the extension piece properly.

10.3 Check visually that the external finish of the complete length of the scope is free from any damage and deformation.

Functional check of the borescope shall be done before carrying out the inspection.

10.4 If both ends of the tube are open and accessible then it shall be ascertained that internal area is free from any obstruction which will hinder the movement of insertion tube.

10.5 Initially for general examination, borescope with direct view shall be used. Before insertion, light shall be switched on and borescope insertion tube shall be inserted slowly inside the object.

10.6 In case, prior inspection of tube to check the presence of any obstacle has not been performed, borescope movement shall be done in steps and at each step inner area shall be viewed through the eye piece. Eye piece shall be focused to obtain a sharp image.

10.7 Distance marking on the insertion tube at regular interval is always helpful in locating the desired area.

10.8 Borescope position for inspecting the region of interest shall be confirmed by the marking made on the insertion tube. Once located, the region of interest shall be inspected all around by giving one full rotation to the insertion tube. While viewing, image shall be focused properly to obtain a sharp image.

10.9 In case more detailed information is required, suspected area in the side wall can be subsequently reexamined using right angle view borescope.

10.10 If the manufacturing history and service condition of the product is known, to some extent, type of surface imperfections or discontinuity can be judged by the visual examination. Further, its location can be reported with the help of some marking on the insertion tube for length and angular position.

10.11 While withdrawing the borescope, light can be switched off.

11 GENERAL GUIDELINES FOR USING VIDEOSCOPE

11.1 Optical adaptor shall be firmly attached to the distal end of the scope and this can be confirmed by switching on the light. The illumination light will not light if it is not correctly attached.

11.2 The illumination light shall be turned on during insertion into the object being examined.

11.3 Scope shall be inserted slowly while observing the monitor screen to confirm the correctness of the insertion direction. Angulations operation as required can be performed during insertion to view the side walls.

11.4 Insertion tube shall be kept as straight as possible to get the best operations from the instrument. During insertion, application of excessive pushing force, twisting or tension to the insertion tube shall be avoided.

11.5 The brightness of the image can be controlled either by gain adjustment or contrast correction. Brightness shall be adjusted as per the requirement.

11.6 Higher gain gives higher brightness but with increased noise. Vertical noise bands may appear for extremely bright area.

11.7 When contrast is higher than the normal it can be corrected by increasing the image brightness. Similarly when contrast is lower than the normal, it can be corrected by decreasing the image brightness.

11.8 Scalar measurement is done by using an object in the observation screen that has a known length as a reference length and then using that value to measure the length of the test object.

11.9 For high accuracy, reference length shall be correct. Further both reference and test objects shall be positioned with the same optical axes and perpendicularity.

11.10 Before withdrawing the scope its angulation shall be unlocked.

12 GENERAL PRECAUTIONS

a) Light source shall be turned off before attaching or detaching the optical adapter. Touching the distal end immediately after having turned off light source may cause burn on the skin;

b) Light emitted from the distal end may cause injury to eye;

c) Always the light button shall be turned off when insertion tube is inside the object and not in use, otherwise the light emitted from the scope may heat a nearby object and cause fire ignition. For the same reason the instrument shall never be used in a flammable atmosphere;

d) The instrument shall not be used in an environment filled with fine particles such as metal dust;

e) Only the insertion tube, of any instrument designed for under water inspection is water resistant. Therefore except for the scope insertion tube, the instrument shall not be used or stored in any location where its control unit, video monitor, light source, power unit might be submerged in water. Otherwise an electric shock may result;

f) In case of water proof instrument the insertion tube should not be brought in contact with a liquid other than water, saline, machine oil and light oil. Any other liquid corrosive in nature may damage the instrument;

g) If the O-ring at the tip or inside the optical adapter is positioned incorrectly, water can get into the joint area between the scope and optical adapter which may cause malfunction or damage. No dirt or water shall be present on the objective lens and the electrodes of the scope distal end otherwise it may cause damage to the optical adaptor or the scope distal end. Lens shall be cleaned by lens cleaning fluid using cotton swab to remove water or dust shall;

h) The amount of screen noise may increase under high ambient temperature. Generally high temperatures warnings are displayed on the screen in case temperature around the scope increases the designed limit;

j) Scope shall not be withdrawn while its angulation is locked, otherwise the scope and/or observation target may be damaged; and

k) The instrument shall never be used in observation inside human and animal cavity. The human body or animal may be injured.

13FACTORSAFFECTINGTHEPERFORMANCE OF BORESCOPES

13.1 Test Object

Objective distance, object size, discontinuity size, reflectivity, entry port size, object depth and direction of view are all critical aspects of the test object that affect the visual test.

13.2 Environment

Most of the scopes can operate at temperatures from –34°C to 66°C. Water proof scopes can be used at pressures above ambient as specified by the manufacturer. Radiation can cause the multi-component lenses and image bundles to turn brown. In radiation atmosphere, use of quartz fiberscope is preferable. Only explosion proof scopes shall use in gaseous environment to minimize the potential of an accidental explosion.

14 APPLICATIONS OF INDUSTRIAL BORESCOPE

14.1 Borescope are widely used during manufacturing, maintenance and in-service inspection in industry. Borescopes are also useful for locating discontinuities such as cracks or blowholes in casting and forgings.

14.2 In production machine operations, borescopes of various sizes and angles of view are used to examine internal holes, bored holes, threads, internal surface finishes. Borescopes are used to inspect cylinders for internal surface finish after honing. Specific examples are, visual tests of machine gun barrels, riffle bores, cannon bores, machine equipment and hydraulic cylinders.

14.3 Engine cylinders can be examined through spark plug holes without removing the cylinder head. Inaccessible areas of hydraulic systems, small pumps, motors and mechanical or electrical assemblies can be visually tested without dismantling the engine.

14.4 In power plants, borescopes are used for visual tests of boiler tubes or steam generator for pitting, corrosion, scaling or other discontinuities.

15 TERMINOLOGIES AND GUIDELINES FOR EQUIPMENT SELECTION

15.1 Lighting

Placement of light source with respect to viewing object for proper illumination. In general, orientation of the light source is an important first consideration. Where ever possible, lighting should originate from the top of the object. Lighting should originate from one direction on most three-dimensional objects to avoid ambiguity in relief, if more light is required, it should be slightly weaker and more diffuse than the main light source.

15.2 Illumination

The act of illuminating any object for making it visible. The required intensity of the light source is determined by the reflectivity of the surface, the area of surface to be illuminated and the transmission losses over the length of the scope. At working lengths greater than 6 m rigid borescopes with clamp at the distal end provide the greatest amount of illumination over the widest area. However, the heat generated by the light source may deform rubber or plastic materials. Fiber optic illumination in scopes with working lengths less than 6 m is always brighter and is suitable for heat-sensitive applications, because filters can remove infrared frequencies.

Because the amount of illumination depends on the diameter of the light guide bundle, it is desirable to use the largest diameter possible.

15.3 Magnification

15.3.1 Increase in the size of the image relative to the object size, when viewed through a lens system. Magnification (M), of a single lens is inversely proportional to its focal length and it is determined by the equation:

M = 250/f (‘f’ in millimeters) or,

M = 10/f (‘f’ in inches)

Where,

M = Magnification, and

F = focal length of the lens, in millimeters/inches.

15.3.2 In this equation f is the focal length of the lens in millimeters (or inches) and 250 (or 10) is constant that represents the average minimum distance at which objects can be distinctly seen by the unaided eye. Using the equation, a lens with a focal length of 125 mm (5 in.) has magnification of two widths or is said to be a two power (2X) lens.

15.3.3 Selection of a magnifier with the proper field of view is important. For example, if the test object is large, it takes too much time to use a 20X magnifier (focal length= 250/20=12.2mm) with a field of view slightly greater than 10 mm. The proper procedure is to use a low magnifier first for marking questionable areas and then to inspect questioned areas with a higher powered magnifier.

15.3.4 Magnification of borescopes optical system is given by the relation, $M = m_1 \times m_2 \times m_3$, where $m_{1,}$ m_2 and m_3 are the magnifications of the objective, middle and ocular lenses respectively. The total magnification of borescopes varies with diameter and length but generally ranges from about 2 to 8 for all common borescopes in use.

15.4 Objective Distance

15.4.1 *Distance of the Object from the Lens*

It is important in determining the illumination source, as well as the required objective focal distance for the maximum power and magnification (*see* Fig. 7).

The linear magnification of a given borescope changes with working distance and is about inversely proportional to the object distance. A borescope with 2X magnification at 25 mm working distance therefore will magnify 4X at 13 mm distance.

15.5 Entry Port Size

15.5.1 *Size of an Opening in an Object for Inserting the Borescope*

It determines the maximum diameter of the instrument that can be used for the visual test (*see* Fig. 8).

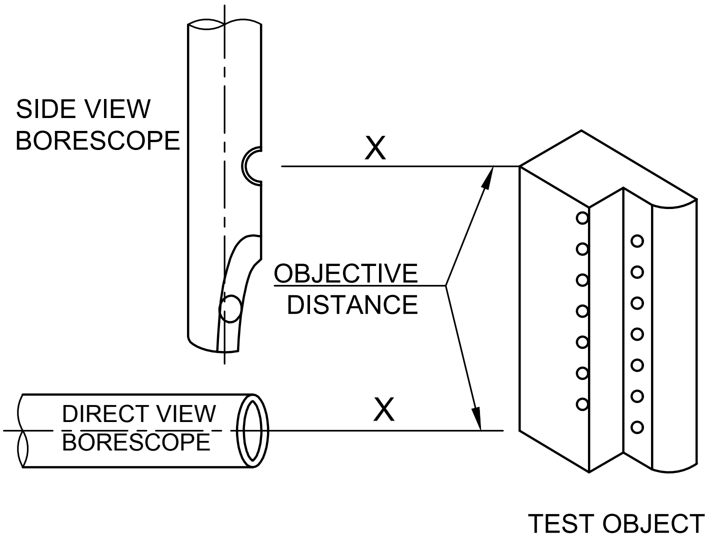


FIG. 7 OBJECTIVE DISTANCE ‘X’

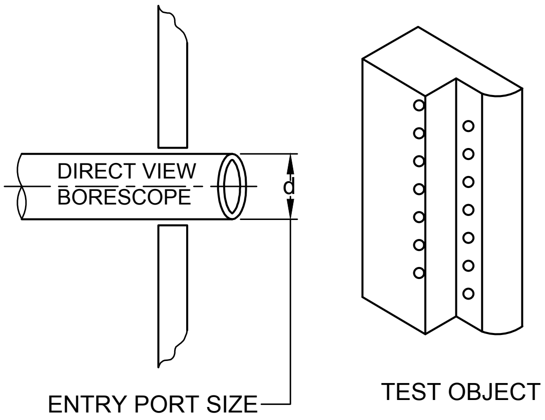


FIG. 8 ENTRY PORT SIZE

15.6 Objective Size

The dimensions of the object to be viewed. Objective size together with objective distance, determines lens angle or field of view required to observe entire test surface.

15.7 Object Depth

15.7.1 *Object Thickness Perpendicular to the Focal Plane in Front of the Lens System*

It affects focusing. If portions of the object are in different planes, then borescope must have sufficient focus adjustment or depth of field to visualize these different planes sharply (*see* Fig. 9).

15.8 Discontinuity Size

15.8.1 *Size of Imperfection on the Object*

It determines the magnification and resolution required for visual testing. For example, greater resolution is required to detect hairline cracks than to detect undercut (*see* Fig. 10).

15.9 Field of View

15.9.1 The field of view is the area seen through the magnifier (*see* Fig. 11 and Fig. 12). With a simple magnifier, the diameter of the field of view is less than its focal length.

15.9.2 There is an inverse relation between the total magnification and the diameter of field of view, as magnification increases the diameter of the field of view decreases in proportion. Specifically, the magnification increases when either the field of view or the lens-to-object distance decreases.

15.9.3 A wide field of view reduces magnification but has greater depth of field. A narrow field of view produces higher magnification but results in shallow depth of field (*see* Fig. 13). Field of view directly varies with the viewing angle and objective distance.

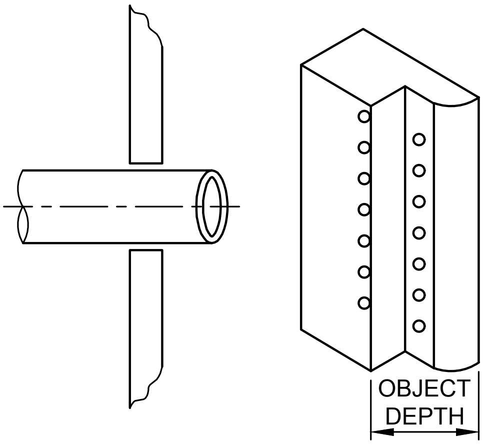


FIG. 9 OBJECT DEPTH

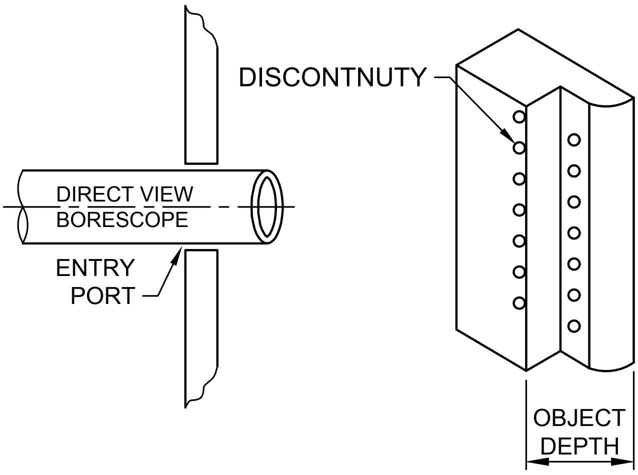


FIG. 10 DISCONTINUITY SIZE

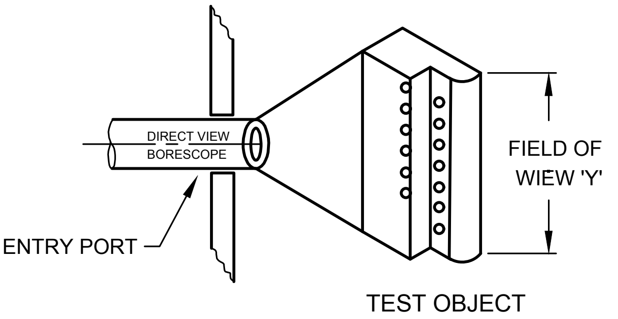


FIG. 11 FIELD OF VIEW FOR DIRECT VIEW BORESCOPE

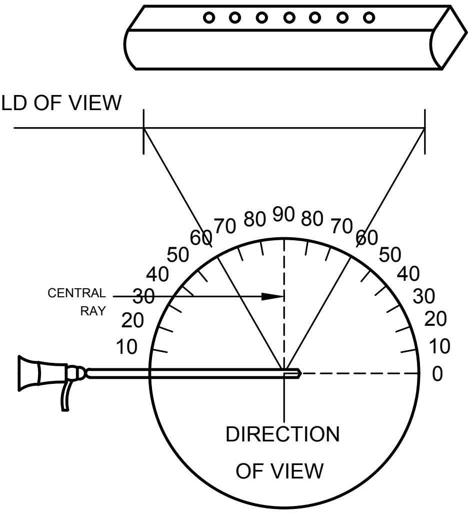
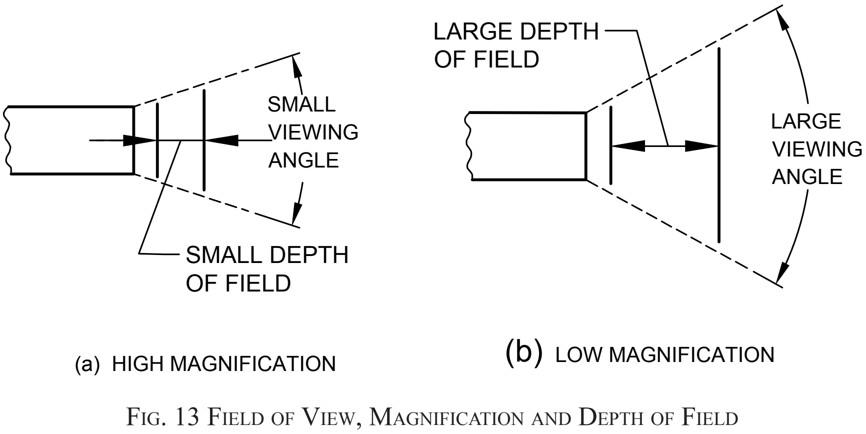


FIG. 12 FIELD OF VIEW FOR SIDE VIEW BORESCOPE



(a) HIGH MAGNIFICATION (b) LOW MAGNIFICATION

FIG. 13 FIELD OF VIEW, MAGNIFICATION AND DEPTH OF FIELD

15.10 Focusing

The act of adjusting the position of a viewed object relative to a lens system for obtaining a distinct image of the object as seen through the lens system. If portions of long objects are at different planes, the scope must have sufficient focus adjustment to achieve an adequate depth of field. If the scope has a fixed focal length, the object will be in focus only at a specific lens-to-object distance.

15.11 Depth of Field

The range of Distance in Focus or Tickness of the Plane of Focus

Denotes the distance magnifier can be moved toward or away from a subject with the subject remaining in good focus (sharply defined). It can also be defined as the range of distance over which borescope gives satisfactory definition, when its lens is in the best focus for a plane, known as principal plane of focus at certain specific distance. At other distances, the subject is out of focus and not sharply defined. Depth of field varies with the power of lens and is comparatively greater in lower power magnifiers. It decreases as the power of the lens increases (*see* Fig. 14).

15.12 Automatic Focusing Feature

The depth of field so much expanded that focusing becomes unnecessary. Since no mechanism is actively adjusted, this feature is called automatic focusing. In a videoscope the expanded depth of field is attributable to both the proximity of the lens to the charge coupled device and the small diameter of the lens aperture.

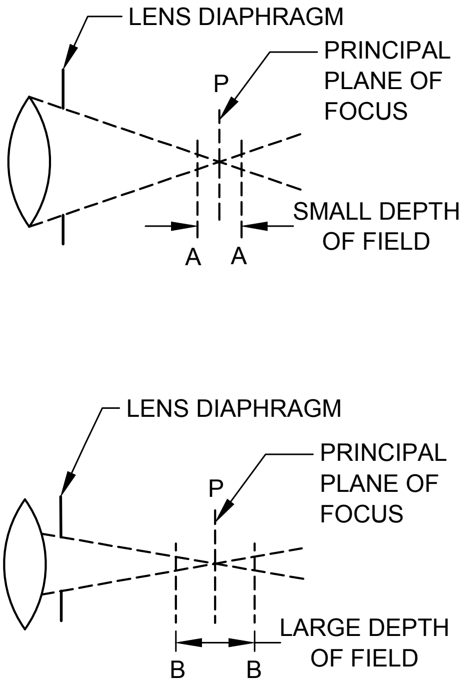


Fig. 14 Depth of Field

15.13 Direction of View

15.13.1 *Viewing Direction with Respect to the long Axis of the Borescope*

It determines positioning of the borescope, especially with rigid borescopes. Viewing direction also contributes to the required length of the borescope. The selection of a viewing direction is influenced by the location of the access port in relation to the object to be observed.

15.13.2 The most common types of borescope head with different direction of views are:

a) direct,
b) right angle,
c) forward oblique, and
d) retrospective view.

15.13.2.1 The forward viewing head permits the inspection of the area directly ahead of the viewing head.

15.13.2.2 Forward oblique heads bend the viewing direction at an angle to the borescope axis permitting the inspection of corners at the end of a bored hole.

15.13.2.3 The right angle (side) viewing head permits the inspection of internal wall of cylinders.

15.13.2.4 The retrospective viewing head bends the cone of view at a retrospective angle to the borescope axis, providing a view of an internal shoulder for its detail surface inspection (*see* Fig. 15).

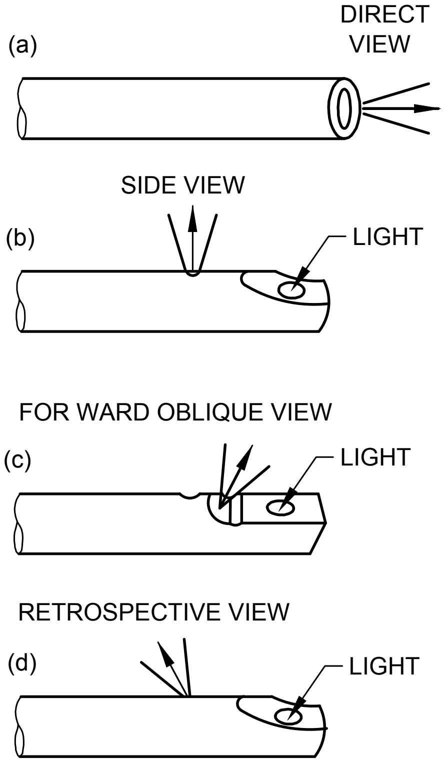


Fig. 15 Direction of View

15.14 Viewing Angle

It is the maximum angular distance in degree in the direction of view in which object can be viewed.

15.15 Angle of Vision

It is the angle of obliquity for the central ray of the visual field, with respect to the forward direction of the borescope axis

Each of direction of view is further characterized by its angle of view. For example, a borescope having retrospective direction of view may have 135 degree angle of vision, which means its central ray makes angle of 135 degree with forward direction of the borescope axis (*see* Fig. 16).

15.16 Reflectivity

The ratio of reflected wave energy to incident wave energy, also known as reflectance.

It is another factor affecting illumination. Dark surfaces such as those coated with carbon deposits require higher levels of illumination than bright surfaces do (*see* Fig. 17).

15.17 Resolution

System’s ability to show two nearby points istinctly often, measured by resolving a pair of adjacent parallel lines.

15.17.1. To allow the observation of surface detail at a desired size, the optical system of a borescope must also provide adequate resolution and image contrast. If resolution is adequate but contrast is lacking, detail cannot be observed.

15.17.2 For fiberscope, the resolution is dependent on the accuracy of alignment and the diameter of the fibers in the image bundle. Smaller-diameter fibers provide more resolution and edge contrast when combined with good geometrical alignment of the fibers.

15.17.3 In general, the optical quality of a rigid borescope improves as the size of the lens increases; consequently, a borescope with the largest possible diameter should be used.

15.18 Borescope Circumferential

Are designed for the inspection of tubing or other cylindrical structures. A centrally located mirror permits right-angle viewing of an area just scanned by the panoramic view.

15.19 Borescope Panoramic

Scanning mirror is mounted in front of the objective lens and its rotation can be adjusted at the viewing end to scan in forward oblique, right angle and retrospective directions.

15.20 Working Length

Total length of the borescope used for visual inspection

In addition to the obvious need for a scope of sufficient length, the working length can sometimes dictate the use of a particular type of scope.

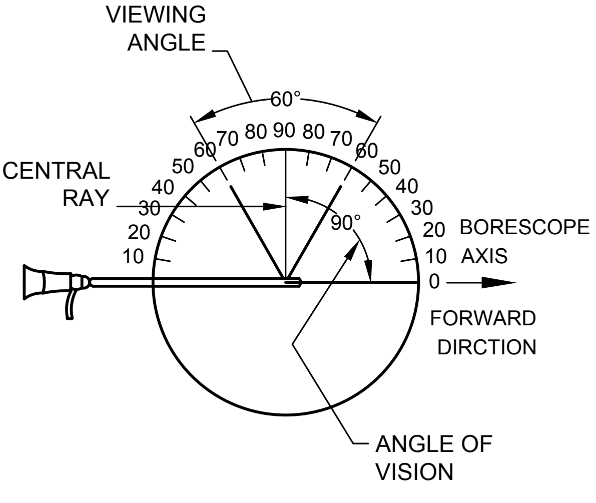


Fig. 16 Angle of Vision

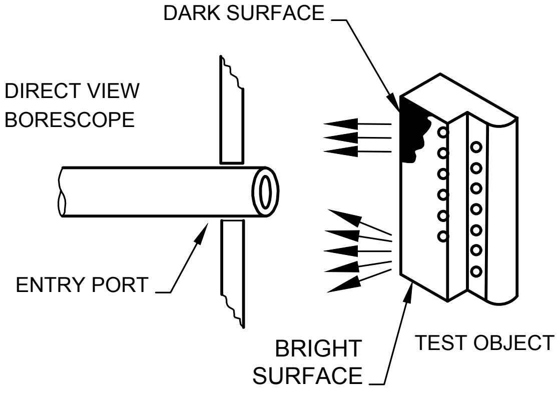


Fig. 17 Reflectively of the Surface

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